## CLAIMS

1. A method of forming a magnetic resonance image, comprising:

providing a plurality of RF receiving coils, each said RF receiving coil having a different spatial sensitivity;

applying one or more RF pulses in combination with one or more gradient encoding steps;

measuring MR signals indicative of nuclear spins caused by the step of applying in the plurality of receiver coils to form a set of MR signals;

generating a set of encoding functions representative a spatial distribution of receiver coil sensitivities and spatial modulations corresponding to the gradient encoding steps;

transforming the set of encoding functions to generate a new set of functions representative of distinct spatial positions in an image; and

applying the new set of functions to the set of MR signals to form the magnetic resonance image.

2. The method of claim 1, wherein generating a set of encoding functions includes forming an encoding matrix, each entry of the encoding matrix comprising:

coil sensitivity of a respective coil combined with a gradient modulation corresponding to a particular gradient encoding step;

transforming the set includes inverting the encoding matrix to form an inverted encoding matrix; and

applying the set of new functions includes:

(a) forming a k-space matrix, each entry of the k-space matrix comprising a measured RF signal indicative of nuclear spins sensed by a respective coil at a particular gradient encoding step, and

(b) multiplying the inverted encoding matrix with the k-space matrix to form the magnetic resonance image.

3. The method of claim 2, wherein the step of inverting the encoding matrix comprises:

selecting a subset of entries of the encoding matrix to form a sub-block;

inverting the sub-block; and

multiplying the inverted sub-block by multiple subsets of the k-space matrix to form the magnetic resonance image.

4. The method of claim 2, further comprising:

performing a Fourier transform along a first distinct direction on entries of the inverted encoding matrix before the step of inverting; and

performing a corresponding Fourier transform along the first distinct direction on entries of the k-space matrix before the step of multiplying.

5. The method of claim 4, further comprising:

performing an additional Fourier transform along a second distinct direction on the transformed entries of the encoding matrix before the step of inverting; and

performing a corresponding additional Fourier transform along the second distinct direction on the transformed entries of the k-space matrix before the step of multiplying.

6. The method of claim 4, further comprising:

forming a separate encoding matrix corresponding to one distinct position along the Fourier transformed direction;

inverting said separate encoding matrix corresponding to that position;

multiplying the inverted encoding matrix by a subset of the Fourier transformed entries of the k-space matrix corresponding to a distinct position along the Fourier transformed direction;

repeating the steps of forming, inverting, and multiplying for additional distinct positions; and

combining the results for the multiple distinct positions to form the magnetic resonance image.

7. The method of claim 4, wherein inverting the encoding matrix comprises:

selecting a subset of entries of the encoding matrix to form a sub-block;

inverting the sub-block; and

multiplying the inverted sub-block by multiple subsets of the k-space matrix to form the magnetic resonance image.

8. The method of claim 7, wherein the sub-block is a single set of rows of entries in the encoding matrix corresponding to coil sensitivities of each coil at a particular phase encode step.

9. The method of claim 7, wherein the sub-block comprises multiple sets of rows of entries in the encoding matrix, each set corresponding to coil sensitivities of the coils at a particular phase encode step.

10. The method of claim 8, further comprising selecting a number of rows in the sub-block based on a quality of the magnetic resonance image.

11. The method of claim 8, further comprising using the results of the sub-block inversion to determine the quality of an actual or prospective coil array design.

12. The method of claim 2, wherein inverting the encoding matrix comprises performing a singular value decomposition of the encoding matrix.

13. The method of claim 2, wherein inverting the encoding matrix comprises performing a matrix least squares pseudoinverse of the encoding matrix.

14. The method of claim 2, wherein eigenvalues of the encoding matrix are conditioned prior to inversion.

15. The method of claim 14, wherein conditioning the eigenvalues comprises at least one of:

eliminating all eigenvalues below an eigenvalue threshold from the inversion;
setting all sub-threshold eigenvalues equal to the threshold value; and
adding the threshold value to all eigenvalues.

16. The method of claim 1, wherein:

generating a set of encoding functions includes forming an encoding matrix, each entry of the encoding matrix comprising a coil sensitivity of a respective coil combined with a gradient modulation corresponding to a particular gradient encoding step:;

transforming the set includes fitting the entries in the encoding matrix to a set of basis functions to form transformation coefficients;

applying the set of new functions includes:

(a) forming a k-space matrix, each entry of the k-space matrix comprising a measured RF signal indicative of nuclear spins sensed by a respective coil at a particular gradient encoding step,

(b) applying the transformation coefficients to the k-space matrix to form a transformed matrix, and

(c) forming the magnetic resonance image from the transformed matrix.

17. The method of claim 16, further comprising:

selecting a subset of entries of the encoding matrix to form a sub-block; and

wherein fitting the entries in the encoding matrix comprises fitting the entries of the sub-block to a set of basis functions to form a sub-block of transformation coefficients;

wherein applying the transformation coefficients comprises applying the sub-block of transformation coefficients to multiple subsets of the measured MR signals in the k-space matrix to form sub-blocks of entries of the transformed matrix.

18. The method of claim 16, wherein the basis functions are spatial harmonics, and wherein the magnetic resonance image is formed by performing a Fourier transform on the entries of the transformed matrix.

19. The method of claim 16, wherein the basis functions are Gaussians.

20. The method of claim 16, wherein the basis functions are wavelets.

21. The method of claim 16, wherein inverting the encoding matrix comprises performing a singular value decomposition of the encoding matrix.

22. The method of claim 16, wherein inverting the encoding matrix comprises performing a matrix least squares pseudoinverse of the encoding matrix.

23. The method of claim 16, wherein eigenvalues of the encoding matrix are conditioned prior to inversion.

24. The method of claim 23, wherein conditioning the eigenvalues comprises at least one of:

eliminating all eigenvalues below an eigenvalue threshold from the inversion;
setting all sub-threshold eigenvalues equal to the threshold value; and
adding the threshold value to all eigenvalues.

25. A apparatus for forming a magnetic resonance image, comprising:

means for applying one or more RF pulses in combination with one or more gradient encoding magnetic fields;

a plurality of RF receiving coils, each said RF receiving coil having a different spatial sensitivity and configured to measure MR signals indicative of nuclear spins perturbed by the means for applying to form a set of MR signals; and

a controller configured to generate a set of encoding functions representative a spatial distribution of receiver coil sensitivities and spatial modulations corresponding to the gradient encoding steps, transform the set of encoding functions to generate a new set of functions representative of distinct spatial positions in an image, and apply the new set of functions to the set of MR signals to form the magnetic resonance image.

26. The apparatus of claim 25 wherein the controller is configured to:

form an encoding matrix, each entry of the encoding matrix comprising a coil sensitivity of a respective coil combined with a gradient modulation corresponding to a particular gradient encoding step;

invert the encoding matrix to form an inverted encoding matrix;

form a k-space matrix, each entry of the k-space matrix comprising a measured RF signal indicative of nuclear spins sensed by a respective coil at a particular gradient encoding step; and

multiply the inverted encoding matrix with the k-space matrix to form the magnetic resonance image.

27. The apparatus of claim 26, wherein the controller is configured to invert the encoding matrix by:

selecting a subset of entries of the encoding matrix to form a sub-block;

inverting the sub-block; and

multiplying the inverted sub-block by multiple subsets of the k-space matrix to form the magnetic resonance image.

28. The apparatus of claim 26, wherein the controller is further configured to perform a Fourier transform along a first distinct direction on entries of the inverted encoding matrix, and perform a corresponding Fourier transform along the first distinct direction on entries of the k-space matrix.

29. The apparatus of claim 28, wherein the controller is further configured to perform an additional Fourier transform along a second distinct direction on the transformed entries of the encoding matrix, and perform a corresponding additional Fourier transform along the second distinct direction on the transformed entries of the k-space matrix.

30. The apparatus of claim 28, wherein the controller is further configured to:

form a separate encoding matrix corresponding to one distinct position along the Fourier transformed direction;

invert said separate encoding matrix corresponding to that position;

multiply the inverted encoding matrix by a subset of the Fourier transformed entries of the k-space matrix corresponding to a distinct position along the Fourier transformed direction;

repeat the steps of forming, inverting, and multiplying for additional distinct positions; and

combine the results for the multiple distinct positions to form the magnetic resonance image.

31. The apparatus of claim 28, wherein the controller is configured to invert the encoding matrix by:

selecting a subset of entries of the encoding matrix to form a sub-block;

inverting the sub-block; and

multiplying the inverted sub-block by multiple subsets of the k-space matrix to form the magnetic resonance image.

32. The apparatus of claim 31, wherein the sub-block is a single set of rows of entries in the encoding matrix corresponding to coil sensitivities of each coil at a particular phase encode step.

33. The apparatus of claim 32, wherein the controller is further configured to select a number of rows in the sub-block based on a quality of the magnetic resonance image.

34. The apparatus of claim 31, wherein the sub-block comprises multiple sets of rows of entries in the encoding matrix, each set corresponding to coil sensitivities of the coils at a particular phase encode step.

35. The apparatus of claim 26, wherein eigenvalues of the encoding matrix are conditioned prior to inversion.

36. The apparatus of claim 25, wherein the controller is configured to:

form an encoding matrix, each entry of the encoding matrix comprising a coil sensitivity of a respective coil combined with a gradient modulation corresponding to a particular encoding gradient;

fit the entries in the encoding matrix to a set of basis functions to form transformation coefficients;

form a k-space matrix, each entry of the k-space matrix comprising a measured RF signal indicative of nuclear spins sensed by a respective coil at a particular gradient encoding step;

apply the transformation coefficients to the k-space matrix to form a transformed matrix; and

form the magnetic resonance image from the transformed matrix.

37. The apparatus of claim 36, wherein the controller is further configured to:

select a subset of entries of the encoding matrix to form a sub-block;

fit the entries in the encoding matrix by fitting the entries of the sub-block to a set of basis functions to form a sub-block of transformation coefficients; and

apply the sub-block of transformation coefficients to multiple subsets of the measured MR signals in the k-space matrix to form sub-blocks of entries of the transformed matrix.

38. The apparatus of claim 36, wherein the basis functions are spatial harmonics, and wherein the magnetic resonance image is formed by performing a Fourier transform on the entries of the transformed matrix.

39. The apparatus of claim 36, wherein eigenvalues of the encoding matrix are conditioned prior to inversion.